CONDITION MONITORING

Summary

There have been many changes in the world of maintenance in the past few years. Predictive maintenance is one of the strategies to be used today to guarantee optimal performance at the lowest possible cost. Condition monitoring is a tool needed for predictive maintenance and the main requirement for it, is that it proves to be cost-effective.

On-line condition monitoring techniques are gaining importance in the field of maintenance, sometimes incorporating on-line diagnoses of the results. These include:

- Data from the process side since it can give a hint of a maintenance related problem.
- Expert systems and statistical process control (SPC) techniques for the evaluation of trends used to support decision making.

For a proper selection of a specific CONDITION MONITORING task it is crucial to know the characteristic of the failure it is meant to prevent.

Most failures give a warning that they are about to occur (potential failure). With condition monitoring deviations from the normal condition are detected. Based on these readings decisions can be made as to what corrective maintenance action has to be carried out and when.

Suggestions are made of guidelines for the proper selection and implementation of condition monitoring tasks and the condition monitoring techniques described.

1. THE MAINTENANCE ENVIRONMENT TODAY

The world of maintenance has drastically changed in the past few years. The requirements have been growing and still are. The main aspects that maintenance has to cope with today are:

- Higher Plant Availability and Reliability
- Greater Cost Effectiveness
- Greater Safety
- Better Product Quality
- No damage to the environment
- Longer Equipment Lifetime

The first two points are focused on, because they are easy to quantify by means of money.

Maintenance strategies have to be selected to produce the lowest overall cost possible.

Overall costs include:

- Prevention cost
- Repair cost
- Secondary damage cost (e.g. a bearing sizes due to a broken tube oil line)
- Loss of production (due to the down time of the equipment)

2. TYPES OF MAINTENANCE TASKS

Apart from servicing it is possible to split maintenance tasks into three types.

Two of them do not need condition monitoring:

- Breakdown Maintenance; where the equipment is left in service until it fails. This can be both, dangerous and expensive.
- Scheduled Overhaul and Exchange; where the equipment, or part of the equipment, is restored or changed irrespective of its state. This is expensive and increases the risk of premature failures.

The third type strongly depends on condition monitoring:

- Predictive Maintenance; where the equipment, or part of the equipment, is to be restored or changed the moment before it fails. One could say "Just in Time".

3. WHAT IS CONDITION MONITORING

For many people "Condition Monitoring" is vibration analysis. In this paper we will look at it in a much broader sense.

Condition monitoring is everything which helps us to establish the state of equipment or the part to be maintained. Based on the findings, it is possible sometimes to estimate the residual lifetime of it.

According to standards [1], condition monitoring can be explained as:

- Measures to establish and evaluate the actual condition.
- It serves to recognize that repair work has become necessary at a time sufficiently early to allow preparation for such work, thereby permitting the work to be performed according to a schedule and avoiding secondary defects.

The term "Inspection" is also often used in this context.

Most failures give some warning of the fact that they are about to occur. This warning is called a potential failure. It can be defined as an identifiable physical (abnormal) condition which indicates that a failure is either about to occur or in the process of occurring.

With different techniques we intend to detect these deviations to the normal condition. These are condition monitoring techniques

Condition monitoring detects deviations to the normal conditions

The actual state of equipment can be established in different ways:

- Continuously or periodically
  On-line measurements or routine checks every certain time period
- Directly or indirectly
  E.g. weight belt / power consumption of the drive
- Qualitatively or quantitatively
  As a measured value or subjective (this noise is louder than normal)
- With or without instruments

4. ADVANTAGES

Predictive maintenance and therefore condition monitoring is applied to reduce overall cost. That means substituting secondary damage and down time cost, by the expense to avoid them (prevention cost). Therefore:

Condition monitoring has to be cost-effective.

Based on experience condition monitoring very often proves to be cost-effective.

The benefits are:

- Prolonged equipment life time
- Minimized unscheduled downtime
- Fewer unnecessary overhauls
- Less stand-by equipment
- More efficient operation
- Increased safety
- Improved quality performance

5. IMPLEMENTING A CONDITION MONITORING TASK

The need for a condition monitoring task can come from various sources:

- Out of the risk assessment process [2]
- From a cost/benefit analysis
- Dictated by law
- etc.

The steps to establish a task can be seen on the flow sheet in Annex 1.

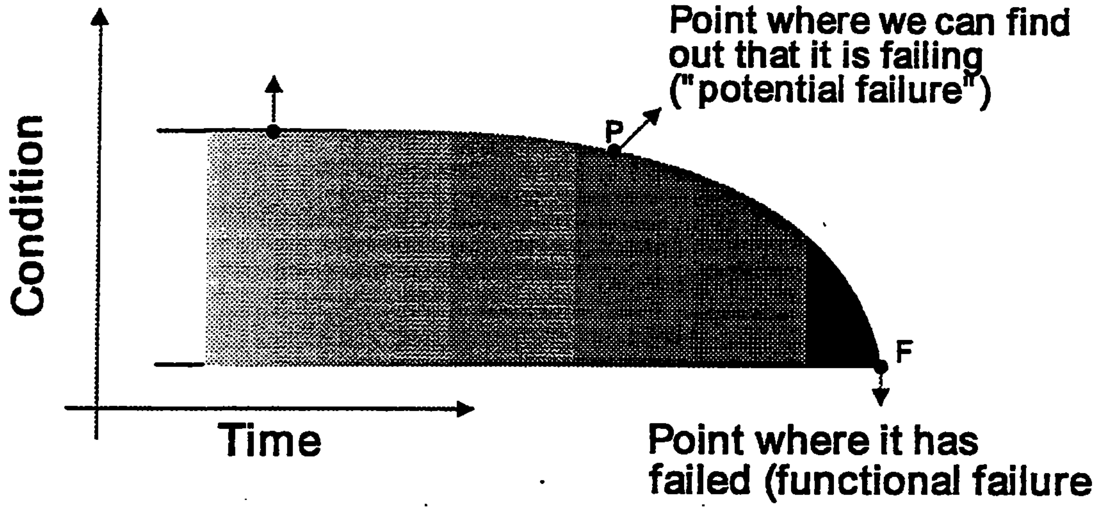
6. THE P-F-CURVE

For the suitable selection of a specific condition monitoring task it is crucial to know the characteristics of the failure it is meant to prevent.

The condition monitored has to have a correlation to the failure; e.g. there is no sense in monitoring the temperature if there will not be a temperature rise before the equipment fails.

The characteristic's in which failures occur can be visualized in a diagram which plots the condition against time. This forms a curve degrading in time. An example with some explanations can be seen in the following picture.

The P-F-Curve



The most common curves are degrading faster in time or are linear.

The function of the curve is not necessarily age related. It can start at any time. But when a failure starts to occur it will progress according to that curve.

The P-F-Interval is the time taken between the occurrence of a potential failure (detection possible) and its decay into the failure itself.

In reality P-F-Interval's are not necessarily consistent. In fact they can vary over a considerable range of values. For most purposes the shortest P-F-Interval should be taken into account.

A sudden impact from the environment (e.g. Overload, foreign object, etc.) can cause a immediate deterioration of the condition into a functional failure. There is no P-F-Interval associated to these kinds of occurrences.

7. LIMITS

There are some limits for the application of condition monitoring.

The failure occurs without warning or too fast to undertake any action (P-F-Interval close to zero); there is no condition monitoring task to prevent it from occurring.

The deviations are too small to be detected or if it is impossible to establish limits for the condition to be monitored.

The P-F-Interval is so inconsistent, that no meaningful task interval can be established. The ultimate limit is given by the cost for the task in comparison to the money saved.

8. HOW OFTEN IS A TASK TO BE PERFORMED

As a guidelines the frequency of a condition monitoring task has to be half of the (shortest) P-F-Interval of the failure. Therefore the frequency for the task depends mainly on two things:

- the characteristic in which a failure occurs
- the deviation needed to detect a potential failure

The characteristics of the failure is predetermined mainly by design and equipment operation. This fact does not give maintenance the possibility to act directly on them.

The only way to influence the frequency is to recognize a potential failure earlier in time. This means the deviation from the normal condition will be less and therefore the method of detecting the deviation has to be more sophisticated.

In the case of a detected abnormal condition (potential failure), the frequency can be adjusted if the repair task will not be carried out immediately and the future development of the failure is not known well (lack of experience, inconsistencies of the P-F-Interval). The idea is to have the equipment, or part, remain in service for as long as possible.

9. CONDITION MONITORING METHODS WITHOUT INSTRUMENTS

The basic condition monitoring methods are use of the human senses:

- sight
- sound
- smell
- touch

They exist as long as mankind and should not be forgotten even in the high-tech-times of today. These methods can be improved on by using simple instruments (magnifying lenses, mirrors, etc.). However, the disadvantage of inspections by human senses are that they are relatively unprecise, and therefore the associated P-F-Intervals are usually very short. Most of the smaller deviations tend to be beyond the range of the human senses and need specialized instruments to be detected.

10. CONDITION MONITORING METHODS USING INSTRUMENTS

We have learnt that a longer P-F-Interval means that the task needs to be done less often, and/or that there is more time to take whatever action is needed to avoid the consequences of the failure. In fact this will save money.

This is why so much effort is being spent on trying to define potential failure conditions and develop techniques for detecting them with the longest possible P-F-Interval (as early as possible).

Still one has to bear in mind that it has to be cost-effective.

10.1 Types of Techniques

In this paper the techniques using instruments are divided into two main groups:

- On-Condition Techniques; where the equipment remains in service
- Inspection Techniques; where the equipment has to be shut down or even dismantled

The above mentioned division is not the only one, neither are the following ones.

Some of the techniques can be used for more than one purpose. In Annex 2 a table can be found with various methods and their possible applications.

10.2 On-Condition Techniques

On-condition techniques have the advantage that the equipment can remain in service. In some cases they even have to be in service; e.g. dynamic measurements. Therefore there is no production loss cost associated with this type of measurement and they do not need special co-ordination with the production. For this reason on-condition techniques have become popular over the past few years. However, they are normally more expensive and the results are sometimes difficult to interpret. Often it is necessary to take baseline readings and decisions have to be based on trends rather than on single measurements.

Very often this type of task is carried out on a regular basis by "inspectors" following a given route in the plant.

A possible way of dividing them into smaller groups is by type of measurements:

- Dynamic; e.g. Vibration Analysis, Acoustic Emission, Torques
- Temperature; e.g. Thermography, Fibre Loop
- Particle and Chemical Analysis; e.g. Spectrometric Oil Analysis, Ferrography
- Electrical; e.g. Meggers, Resistance

10.3 Inspection Techniques

Many inspection techniques are well known and have been used in the cement industry for a long time.

They include a wide range of solutions from simply determining the length with a tape measure to x-ray testing where expensive equipment is needed and good skills are necessary to handle them.

A possible way of dividing them into smaller groups is by the failure they detect:

- Surface Degradation (Wear, Corrosion, Cracks, a.s.o.); e.g. Magnetic Particle Test, Dye Penetration Test, Endoscopy
- Internal Deficiencies; e.g. Ultrasonic Measurements, X-Ray Testing
- Properties; e.g. Hardness Test
- Dimensions; e.g. Meters, Calibration, Shell test
- Alignment; e.g. Laser Distance Measurements, Lead Wire
- Leaks; e.g. Pressure Testing, Ultrasonic Leak Detection

10.4 List of Techniques

In Annex 3 different condition monitoring techniques are described in detail. For every technique the following parameters are given:

- Condition moitored
- Applications
- Technical Base
- P-F-Interval
- Advantages/Disadvantages
- Skills necessary
- Standards applied
- Approx. Cost
- Supplier/Products

11. OUTLOOK

Taking into consideration all maintenance methods applied today a major movement towards on-condition monitoring techniques can be seen. This movement is expected to continue and to accelerate in the future.

Together with the on-line monitoring the on-line diagnoses of the results will gain in attraction, because the expert systems have, and still are becoming more powerful and easier to handle.

To involve process data into the condition monitoring is another step on the way to "Excellence in Maintenance". A higher power consumption of the equipment or a quantity/quality decrease of the product can be a hint of a maintenance related problem.

With the availability of long term data, statistical process control (SPC) techniques for the evaluation of trends can be used to help determine the actual condition of an equipment. Apart from others, two valuable tools to be applied for condition monitoring are:

- Moving X-bar Charts
- EWMA Charts (Exponentially Weighted Moving Average)

Both of them cope with the small amount of measured values available over the time period.

For the evaluation of on-line data (process or maintenance) a much wider field of SPC-techniques are worthwhile for consideration.

12. CONCLUSION

Condition monitoring is a tool needed for predictive maintenance. It is one of the tools for state of the art maintenance to cope with the requirements that it is confronted with; basically to guarantee optimal performance at the lowest possible cost. Therefore, every condition monitoring task has to prove to be cost-effective.

For the proper selection of a specific task it is crucial to know the characteristic's of the failure it is meant to prevent.

Most failures give a warning of the fact that they are about to occur (potential failure). With condition monitoring, deviations to the normal condition are detected. Based on these readings, decisions can be made regarding what maintenance action has to be carried out and when.

As a guideline the frequency of a task has to be half of the P-F-Interval of the failure, i.e. half of the time to elapse between the possible detection of a potential failure and its decay into the failure itself. The only way to lower the frequency is to recognize a potential failure earlier in time. This means the deviation from the normal condition will be less and the method of detecting it has to be more sophisticated.

On-line techniques are gaining importance in the field of maintenance, sometimes incorporating on-line diagnose of the results.

Data from the process side has to be involved as well, since it can give a hint of maintenance related problem.

Expert systems and statistical process control (SPC) techniques for the evaluation of trends can be used to support decision making.

13. REFERENCES

[1] BS 3811; British Standard Nº 3811; Maintenance terms in tero technology, 1974

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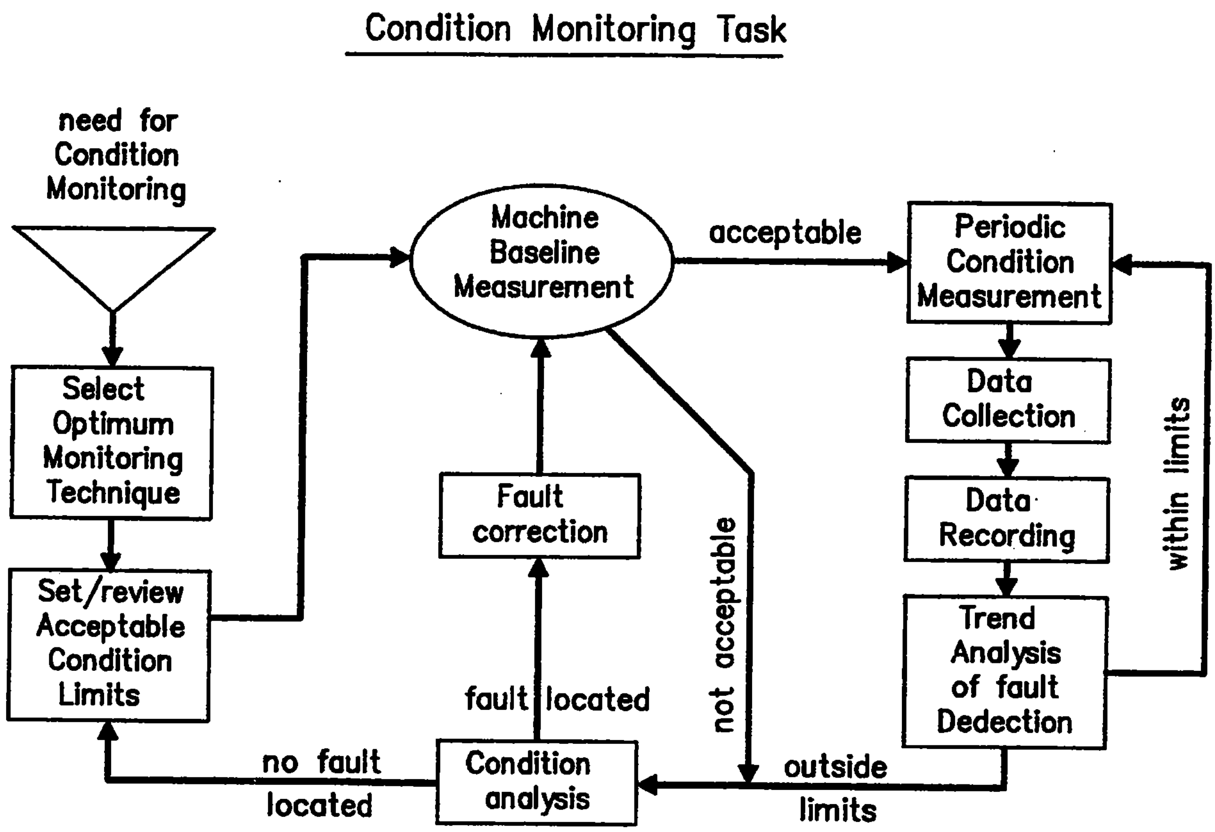
14. ANNEXES

14.1 Condition Monitoring Task



14.2 Condition Monitoring Techniques and their Applications

14.2.1 Annex 2.1

On-Condition Techniques

MAIN APPLICATIONS / TECHNIQUE	Cracks	Wear	Fractures	Corrosion	Erosion	Leaks	Composition	Properties	Stress	Deformation	Dimensions	Deposits	Alignment	Loose/Thightness
Acoustic emission	X		X			X		X		X			X	X
Graded Filtration		X		X										
Ferrography		X		X										
Magnetic plugs		X												
Shelltest										X				
Lead Wire Test										X			X	
Thermometers,-Couples	X	X							X					
Spectrometric oil analysis		X		X										
Strain gauge									X	X				
Stroboscopy	X	X	X										X	
Test Coupons				X	X									
Thermography	X			X		X						X		X
Temperature Indicating Paint						X						X		
Vibration monitoring	X	X	X					X					X	X
Visual Inspection	X	X	X	X	X	X	X			X		X		X
Sight	X	X	X	X	X	X				X		X		X
Sound		X							X				X	X
Smell						X			X					
Touch		X						X						X
SPM (Shock Pulse Monitoring	X	X	X					X					X	X

14.2.2 Annex 2.2

Inspection Techniques

TECHNIQUE \ MAIN APPLICATIONS	Cracks	Wear	Fractures	Corrosion	Erosion	Leaks	Composition	Properties	Stress	Deformation	Dimensions	Deposits	Alignment	Loose/Thightness
Dye penetrant examination	X		X			X								
Eddy current testing	X	X	X	X	X	X					X	X		
Endoscopy	X	X	X	X	X	X						X		
ER-probe				X										
Hardness testing								X						
Dimension Measurement		X		X	X						X	X	X	
Laser distance measurements		X									X		X	
Theodolit											X		X	
Leak testing						X								
Meggers/Voltage Generators								X						
Magnetic particle examination	X													
Engineer's Blue, Oilproof laquer										X			X	
Replica (Electron fractography)	X		X					X		X				
Pressure testing	X		X			X				X				
Radiography (X-Ray)	X	X	X	X	X	X					X	X	X	
Linear Polarisation Resistance				X										
Liquid Chromatography		X		X										
Ultrasonics	X	X	X	X	X	X		X	X	X	X			
Potential Monitoring				X										

14.3 Annexes 3

14.3.1 Acoustic Emission

Conditions monitored

Plastic deformation and crack formations caused by fatigue, stress and wear.

Applications

Metal materials used in structures, pressure vessels, pipelines and mining excavations.

Technical Base

Stress waves are emitted by the materials which are subjected to loads, due to the crystallographic changes. These stress waves are received by a transducer and amplified at an impulse analyser and fed to a X-Y plotter or an oscilloscope. The curve is evaluated visually.

P-F Interval

Several weeks, depending on the application

Experience and knowledge necessary

Equipment functioning and interpretation of the results: An experienced and trained technician

Advantages

Remote detection of flaws: Covers entire structures: Measuring system set up very quickly: High sensitivity: Only limited access to test objects required: Detects active flaws: Only relatively low loads are required. Can sometimes be used to forecast failure load.

Disadvantages

The structure has to be loaded: A-E activity is highly dependent on materials: Irrelevant electrical and mechanical noise can interfere with measurements: Gives limited information on the type of flaw: Interpretation of results may be difficult.

Standards

ASTM in preparation

Estimated Costs

Ultraprobe USD 6'000.—

Stethoscopes USD 1'000.—

Supplier/Products

SPM/ELS-12

Keel Engineering (CH) / Ultraprobe

Westhill (South Africa)

14.3.2 Graded Filtration

Conditions monitored

Particles in lubricating oils (such as iron, copper, lead, chromium, aluminium, silicon, etc.) caused by wear, fatigue and corrosion.

Applications

Enclosed lubricating and hydraulic oil systems, such as gearboxes, engine sumps, hydraulic systems, etc.

Technical Base

An oil sample is diluted and passed through a series of membranes (filters) with decreasing particle passing size. The collected particles are counted under a microscope according to the element and size. Its statistical distribution is shown in a graphical form. The analysis of the characteristics of the distribution of the particles shows whether the wear is normal or not.

P-F Interval

Usually from several weeks to months.

Experience and knowledge necessary

Sample: a laboratory assistant; analysis of the characteristics for the distribution of the particles: An experienced laboratory technician or an engineer.

Advantages

Can determine whether wear is normal or not. Relatively cheap. Can be used to compare one element with another.

Disadvantages

It is not an on-line technique: A high degree of experience is necessary to interpret the results of the sample. Identification of particle elements is difficult

Standards

ISO 4406

Estimated Costs

USD 2'000.—

Supplier/Products

Schak 01 (CH)

Cortec Corporation (USA)

14.3.3 Ferrography

Conditions monitored

Wear, corrosion and fatigue

Applications

Enclosed lubricating and hydraulic oil systems such as gearboxes, engine sumps, hydraulics, etc.

Technical Base

Wear particles are separated magnetically from the lubricating oils onto an inclined glass plate by means of a instrument known as a ferrograph. The particles are distributed along the length of the slide according to their size. The slide is treated so that the particles adhere to the surface when the oil is removed. The total density of the particles and the ratio of large to small particles indicates the type of extent of wear and the analysis is made by means of a technique which is known as bichromatic microscopic examination. An electron microscope can also be used to determine the particles shapes and provide an indication of the cause of the failure.

P-F Interval

Usually several months

Experience and knowledge necessary

To extract the sample and operate the ferrograph: A semi-specialized operative suitable trained. To analyse the ferrogram: An experienced technician.

Advantages

More sensitive than the emission spectrometry at the at early stage of engine wear: measures particles shapes and sizes.

Disadvantages

It is not an on-line technique: measures only the ferrormagnetical particles: Requires an electron microscope for a more profound analysis.

Standards

Estimated Costs

Supplier/Products

BP, Mobil

14.3.4 Magnetic Plugs

Conditions monitored

Wear and fatigue

Applications

Equipment with closed lubrication systems, such as reductors, collectors of motor oil, compressors, etc.

Technical Base

In the lubrication system a magnetic plug is mounted so that it is exposed to the circulating lubricant. The small metal particles in suspension in the oil and the unfastened metal scales due to fatigue, are captured by the magnetic force. The probe is taken out by regular intervals and the adhering particles are examined under a microscope. An increase in the quantity and size of the particles indicates a potential failure. The particles have different characteristics (form, colour and structure) according to the type and location of the failure.

P-F Interval

From days to weeks

Experience and knowledge necessary

To pick up a sample: A semi-specialized operator trained accordingly. To analyse the particles: An experienced and trained technician.

Advantages

It is a cheap method to monitor the contamination of liquids. Only a ordinary microscope is required to analyse the particles. Some plugs may be taken out during operation.

Disadvantages

Short P-F interval: Experience is necessary to interpret the results.

Standards

Estimated Costs

Supplier/Products

14.3.5 SHELLTEST

Conditions monitored

The deformation of the shell of a rotary kiln, rigidity of shell and tyre and the play between them.

Applications

Shell of rotary kilns

Technical Base

The linear movements of a pin which is in contact with the surface of the shell is registered on a paper during a complete revolution of the kiln. There exist mathematical relations to the deformations of the shell. This procedure is carried out three times every 120° of the circumference of the kiln at various planes. Additionally the relative movement between the tyre and the shell is measured placing the pin on the shell and a plate with a paper on the tyre.

P-F Interval

Usually several months.

Experience and knowledge necessary

An experienced operator

Advantages

It is an on-line technique; long p-f intervals

Disadvantages

The evaluation of the results needs experience. Kiln operation does have a significant influence on the mesurement results.

Standards

Estimated Costs

Shelltest equipment USD 10'000

Supplier/Products

HMC "Holderbank"

Phillips

14.3.6 Lead Wire Test

Conditions monitored

Alignment, contact area

Applications

Alignment of tyre / roller kiln

Technical Base

A lead wire is passed between the tyre and a roller. The moulding of the wire is drawn on a sheet. This procedure is carried out three times per tyre every 120° of the its circumference for both rollers. The form of the wire is evaluated for: alignment, straightness of the surface, contact area and stress points.

P-F Interval

Usually several months

Experience and knowledge necessary

No experienced or special knowledge is required

Advantages

Cheap and easy, it is an on-line technique.

Disadvantages

There is no quantitative result; additional measurements are required (oil film on the shoulders) for the evaluation of the alignment of the rollers. Kiln operation does have a significant influence on the measurement results.

Standards

Estimated Costs

< USD 100

Supplier/Products

14.3.7 Thermometer, Thermocouple

Conditions monitored

Elevated temperatures due to wear, overloading, etc. at the surface or inside of an equipment

Applications

Refractory, reductors, motors, etc.

Technical Base

The electrical resistance of a wire changes with the temperature. The tension loss over the resistance is measured. In case of a PT100 the resistance at 20°C is 100 Ohm.

P-F Interval

From several hours to several days depending on the application.

Experience and knowledge necessary

Permanent installation: A specialist. Measurements with portable equipment: A suitable trained semi-specialized operator

Advantages

Cheap and easy to apply the portable equipment: often used as on-line measurement through the process control system

Disadvantages

In some cases the P-F interval is short - various hours

Standards

Estimated Costs

PT100: > USD 200

Digital thermometers: > USD 1'500

Supplier/Products

Rikenta (CH); Ahlborn (D); Endress + Hauser

Keithley, Bailey, Foxboro, Kent

14.3.8 Spectrometric Oil Analysis

Conditions monitored

The wear of the following elements can be detected: iron, copper, lead, chrome, aluminium, molybdenum, tin, silver, zinc, nickel, silicon, sodium, boron

Applications

Circulating oil systems

Technical Base

The contaminants in a sample of oil are measured by emission or atomic absorption spectrometry. The emission spectrometry excites the metallic impurities in the sample with a direct high voltage (15'000 V), causing the impurities to emit characteristic radiation's which can be analysed.

The atomic absorption spectrometry works on the principle that every atom absorbs light of its own specific wave length. The oil sample is diluted and vaporised in an acetylene flame, and the presence of each element is determined using a light source of the appropriate wave length. In this way, the wear particles are identified, quantified and qualified so that the source of deterioration can be located. The graphs of the wear rates for each metal show deteriorating or improving conditions.

P-F Interval

Usually from several weeks to months.

Experience and knowledge necessary

To take out a sample: A semi-specialized, suitable trained operator. To operate the spectrometer: a trained laboratory technician. To analyse the results of the sample: an experienced chemical analyst.

Advantages

This test, of atom absorption, is comparatively cheap (sometimes it can be included in the service of the oil supplier): More reproducible at lower concentrations: Emission spectrometry is much faster than the atomic absorption spectrometry.

Disadvantages

Normally the analysis have to be made by specialised contractors (or oil suppliers) because the equipment and experience is lacking (long response time).

Standards

Estimated Costs

Supplier/Products

BP, Mobil

14.3.9 Strain Gauges

Conditions monitored

Forces and deformations on parts

Applications

Gear reductor, structures, shafts, drives, etc.

Technical Base

The resistance of the wire changes linearly to the prolongation caused by the deformations. This resistance is measured by a bridge circuit.

P-F Interval

Several weeks to several months

Experience and knowledge necessary

An experienced technician is required to decide the position and affix the strain gauges as well as evaluate the results.

Advantages

Long P-F interval

Disadvantages

The measuring equipment are expensive, an external expert is required.

Standards

Estimated Costs

Supplier/Products

MEC; Brüel & Kjær

14.3.10 Stroposcopy

Conditions monitored

Fissures, wear, direction, rotation speed and alignment in rotating and oscillating parts.

Applications

Rotary equipment such as shafts, ventilators, etc. for fissures or wear; check coupling for distance between the plates, loose screws, etc., balancing of rotary equipment (together with vibration measurement equipment)

Technical Base

The eyes follow the movement of one part in relation to the frequency in which it is illuminated. The frequency of the stroboscope is adjusted until the part appears to be stationary. Then the part can be inspected.

P-F Interval

Depends on the application; from several days to weeks

Experience and knowledge necessary

No experience or special knowledge is required.

Advantages

Easy to use and cheap, it is an on-line technique.

Disadvantages

Gives the impression that the part does not move, therefore security aspect should be kept in mind.

Standards

Estimated Costs

USD 500

Supplier/Products

Picostrob; Tourostrob

14.3.11 Test Coupon

Conditions monitored

General and localised erosion and corrosion such as metal loss and pitting

Applications

Petrol refineries, process plants, gas transmission plants, underground structures, monitoring of cathode protection, abrasive slurry transport, water distribution systems, atmospherique corrosion.

Technical Base

Usually coupons are produced from mild, low carbon steel with a low coal content or of a grade material which duplicates the wall of a vessel or pipe. The coupons are carefully prepared, weighted and measured before they will be exposed. After the coupons have been submerged in the process flow for a period of time (from several weeks to several months) they are removed and checked for weight loss and pitting. From these measurements, the relative metal loss of the tube walls can be calculated and pitting can be estimated.

P-F Interval

Several months

Experience and knowledge necessary

A suitable trained specialist

Advantages

Very satisfactory when corrosion is constant: Useful in dangerous areas where the electrical dispositives are prohibited: Fairly cheap: Indicates the type of corrosion: Widely used.

Disadvantages

Results take time: The response to dangerous corrosive conditions is low: The use of coupons requires several personnel: The determination of the rate of corrosion usually takes several weeks: Information about temporal or abnormal conditions are not supplied.

Standards

Estimated Costs

Supplier/Products

14.3.12 Thermography

Conditions monitored

Temperature variances caused by wear, corrosion, fatigue, leaks, poor electrical connections, etc.

Applications

Power transmission lines, transformers, refractories, electrical switchgear, building insulation, hydraulics, bearings, gas mains (dirt accumulations), etc.

Technical Base

Thermography extends the human vision to infrared waves. It is based on the principal that all objects above absolute zero (-273°C) emit infra-red radiation. An infrared camera that produces a live thermal picture detects this energy. Temperature differences of the surface are seen as light and dark areas and false colours. The thermal drawing can be recorded by a video camera attached to the display screen or directly onto a floppy-disk.

P-F Interval

A few days to several months depending on the application

Experience and knowledge necessary

Operation of equipment: A trained specialist. Interpretation of results: An experienced technician.

Advantages

Stationary or moving objects can be examined at any distance without touching or influencing the temperature of the object: Photographs and videotapes provide a permanent record: Examinations are carried out at safe distances from dangerous gases and high temperatures: Equipment portable and quick to use.

Disadvantages

Inaccessible components have to be uncovered: Costs: Needs specialist to interpret results: wide range of applications are needed to justify cost of the equipment.

Standards

Estimated Costs

Portable systems USD 1'500 - 6'000

Complete systems (including software) USD 50'-100'000

Supplier/Products

AGEMA: Thermovision

AHLBORN: Raynger

HENZ: Infratherm

Land (USA); Williamson (USA); Kane May

14.3.13 Temperature Indicating Paint

Conditions monitored

Equipment temperature at surface

Applications

Refractories, thermal treatment

Technical Base

A chemical substance is applied to the machine surface. If the temperature exceeds the design temperature of the substance, the state changes from solid to liquid. Although the temperature is lowered afterwards, the traces of the liquid are still visible.

P-F Interval

From days to several weeks depending on the application

Experience and knowledge necessary

No experience of special knowledge is required.

Advantages

Cheap and easy to use; provides a maximal temperature indication

Disadvantages

Indicates only a temperature limit; several paints are needed to cover temperature range; Once the temperature has been exceeded a new paint is required.

Standards

Estimated Costs

USD 30 per tube or pencil

Supplier/Products

Medicina (FL): Tempil

14.3.14 Vibration Monitoring

Conditions monitored

Changes in the vibration frequencies caused by wear, fatigue, corrosion, imbalances, disalingnment, loosening, etc.

Applications

Rotating and oscillating machines in general such as reductors, ventilators, motors, etc.

Technical Base

Vibrations are produced by the movement of the machine or a part of it. The most important characteristics that can be measured are: displacement, speed, acceleration, frequency, phase, using an accelerator or a speed sensor, a vibrometer, filters, oscilloscopes, etc. Several methods exist to evaluate the vibrations (e.g. wide band, broad band, octave band, etc.) each of them has its advantage for a special problem

P-F Interval

From days to weeks depending on the application

Experience and knowledge necessary

To operate the measuring equipment: an appropriate trained technician; To interpret the results: An experienced technician, sometimes of superior level

Advantages

Cheap and compact: Test during service; can be portable or permanently installed. The interpretation can be based on established acceptance criteria for the condition such as VDI 2056

Disadvantages

An in depth analysis requires an expert and a relatively long analysing time. Different evaluation techniques are needed to cover a case in detail

Standards

VDI 2056 ISO 3945

Estimated Costs

Simple Instrument USD 1'000

Date collector, including software approx. USD 30'000

On-line system for several measuring points > USD 60'000

Supplier/Products

IRD; Bruel & Kjaer; Karl Deutsch; Schenk, MAAG, ABB; SPM

14.3.15 Visual Inspection

Conditions monitored

The range of conditions is enormous: Function, condition, surface, integrity, dimensions, shape, material, etc. of a piece of equipment in any industry not only for condition monitoring but also for damage analysis

Applications

For all equipment

Technical Base

Human sense is the technical base, sometimes supported with simple auxiliary instruments such as mirrors, lamps, etc.

P-F Interval

From several days to several months depending on the application

Experience and knowledge necessary

An attentive operator

Advantages

Most important method; cheap and easy, can be realised by operators of every level and education

Disadvantages

Human senses are limited: results are subjective and sometimes they can not be quantified.

Standards

DIN58220; DIN 8524; DIN 8563

BS 5289; BS 4080; ISO 3058; ASME sect V Art. 9

Estimated Costs

Nothing for inspections that are carried out during the daily work.

Supplier/Products

14.3.16 Sight

Conditions monitored

The range is enormous: Function, condition, surface, integrity, dimensions, shape, material, etc. of an equipment or of a part of any industry not only for condition monitoring but also for damage analysis.

Applications

For all equipment

Technical Base

Use of eyes

P-F Interval

From several days to several months depending on the application

Experience and knowledge necessary

An attentive operator

Advantages

Very important method; cheap and easy, can be realised by on an every day base.

Disadvantages

Human senses are limited; results are subjective and sometimes they can not be quantified.

Standards

DIN 58220; DIN 8524; DIN 8563

BS 5289; BS 4080; ISO 3058; ASME sect V Art. 9

Estimated Costs

Nothing for inspections made by the operators during the daily work

Supplier/Products

14.3.17 Sound

Conditions monitored

In majority: loosening, wear and forces

Applications

For all equipment or moving parts

Technical Base

Use of ears

P-F Interval

From several hours to several months depending on the application

Experience and knowledge necessary

An attentive operator

Advantages

Very important method: cheap and easy, can be realised by operators

Disadvantages

Human senses are limited, results are subjective and sometimes they can not be quantified.

Standards

Estimated Costs

Nothing for inspections made by the operators during the daily work

Supplier/Products

14.3.18 Smell

Conditions monitored

In majority leaks and forces (overloads)

Applications

For all equipment or moving parts, electrical, tubes, tanks, etc.

Technical Base

Use of nose

P-F Interval

From minutes to several hours depending on the application

Experience and knowledge necessary

An attentive operator

Advantages

Cheap and easy, can be realised by operators

Disadvantages

Human senses are limited; results are subjective and sometimes they can not be quantified, P-F interval is very short.

Standards

Estimated Costs

Nothing for inspections made by operators during the daily work

Supplier/Products

14.3.19 Touch

Conditions monitored

In majority loosening, wear and property

Applications

For all equipment

Technical Base

Use of hands

P-F Interval

From several hours to several months depending on the application

Experience and knowledge necessary

An attentive operator

Advantages

Cheap and easy, can be realised by operators

Disadvantages

Human senses are limited; results are subjective and sometimes they can not be quantified; can be dangerous (hot surfaces, splinters, etc.)

Standards

Estimated Costs

Nothing for inspections made by operators during the daily work

Supplier/Products

14.3.20 SPM (Shock Pulse Method)

Conditions monitored

Shock waves due to fissures, wear, disalignment, insufficient lubrication, etc.

Applications

Rolling element bearings, pneumatic impact tools, valves of internal combustion engines

Technical Base

A accelerator detects the shock waves transmitted by the machine. The signals passes through a band pass filter which selects only frequencies exceeding 10 kHz. This high frequency input is converted into square pulses. The peak values of these pulses are read off as a measure of bearing damage.

P-F Interval

Depends on the application, but usually several weeks to months

Experience and knowledge necessary

An experienced and suitably trained technician

Advantages

Long P-F intervals: Equipment portable: Simple to use, on-line technique

Disadvantages

Not suitable for slow-moving machinery with high levels of product impact noise unless adaptive noise cancelling" is also used. Application is limited to a shock impulse measurement and transitory signals.

Standards

Estimated Costs

USD 3'000

Supplier/Products

SPM Instrument AG

AE Advanced Engineering, Rolle (CH)

14.3.21 Dye Penetrant Examination

Conditions monitored

Surface discontinuities, fissures, etc. caused by fatigue, wear, surface shrinkage, grinding, heat treatment, laminations, corrosion, corrosion stresses

Applications

Ferrous and non ferrous materials such as welds, machined surfaces, shafts, boilers, plastic structures, compressor receivers, etc.

Technical Base

The penetrant liquid is applied to the test surface and sufficient time is permitted for it to penetrate the surface discontinuity. The excess surface penetrant is removed. A developer is applied which draws the penetrant from the discontinuity to the test surface where it is interpreted and evaluated. The liquid penetrants are categorised according to the dye type (visible dye, fluorescent or penetrates of double sensity) and the required procedure to eliminate them from the test surface (washable with water, post emulsified or solvent removed)

P-F Interval

From several days to several months depending on the application

Experience and knowledge necessary

To apply the penetrate: a semi-specialized suitable trained operator. Interpretation: A suitable experienced technician

Advantages

The sets of visible penetrate dye are very cheap but the fluorescent sets are a lot more sensitive. Detects surface discontinuities also on non ferrous materials.

Disadvantages

Fluorescent penetrates require an darkened area for inspection; Not an on-line technique, monitors only surface-breaking defects; It cannot verify materials with a porous surface; use is limited at temperatures from 0° to 50°C.

Standards

DIN 54152; BS 4416

ASTM-E 165; MIL-I-25135

Estimated Costs

USD 40 per set

Supplier/Products

ARDROX; MAGNAFLUX; CASTROL

14.3.22 Eddy Current Testing

Conditions monitored

Surface and sub-surface discontinuities caused by wear, fatigue and stress, detection of dimensional changes produced trough wear, strain and corrosion, determination of material hardness.

Applications

Ferrous materials used for boiler tubes, heat exchanger tubes, hydraulic tubing, hoist ropes, railway lines, etc.

Technical Base

A test coil carrying alternating current between 100 kHz and 4 MHz induces eddy current in the part being inspected. Eddy current detours around cracks, becoming compressed, delayed and weakened. The electrical reaction on the test coil is amplified and recorded on a cathode ray tube or direct reading meter.

P-F Interval

Several weeks, depending on the application

Experience and knowledge necessary

An experienced and suitable trained technician.

Advantages

Applicable to a wide range of conducting materials. Can work without surface preparation. High defect detection sensitivity: Strip chart recorder provides a permanent record

Disadvantages

Poor response from non-ferrous materials. Usually an external specialist is required.

Standards

ASNT; DIN

Estimated Costs

from USD 3'000

Supplier/Products

Förster (Germany)

14.3.23 Endoscopy

Conditions monitored

Surface cracks and their orientation, oxide films, weld defects, corrosion, wear, leaks

Applications

The internal visual inspection of narrow tubes, bores and chambers of engines, pumps, turbines, compressors, boilers, etc. in several industries

Technical Base

These instruments are known as endoscopes or borescopes. The light is channelled with mirrors or fibre cables to allow inspection of otherwise inaccessible points of view. If the light is insufficient, an external light can be sent through some of the fibre cables. For this an equipment producing cold light is used. It lightens the area so that photographs can be taken or video equipment used.

P-F Interval

Several weeks depending on the application

Experience and knowledge necessary

An experienced and suitable trained operator

Advantages

A detailed inspection of the surface in inaccessible areas can be obtained without having to dismantle the pieces; photographs can be taken to provide permanent records. They can be magnified; portable equipment.

Disadvantages

Only surface defects can be detected; Not an on-line technique; when equipment with cold light source, video camera, etc. is used, the method becomes costly

Standards

Estimated Costs

Inflexible: USD 2'000; with fibre cables USD 5'000-10'000

Complete systems: USD 30'000-50'000

Supplier/Products

Volpi; Classen + Co; Olympus

14.3.24 Electrical Resistance (Corrometer)

Conditions monitored

Integrated metal loss (i.e.: total corrosion)

Applications

Petroleum refineries, process plants, gas transmission plants, underground structures, cathodic protection monitoring, abrasive slurry transport, water distribution systems, atmospheric corrosion

Technical Base

The system is composed of a probe and an instrument to read it. The probe consists of a wire, strip or tube of the same metal in the plant being monitored. The electric resistance of the probe which is measured by a bridge circuit, increases as the probe cross-section decreases with corrosion. This increase in resistance enables total metal loss to be read out which is easily converted to corrosion rate

P-F Interval

Depends on the application and on the corrosion rate. Usually several months.

Experience and knowledge necessary

A trained specialist

Advantages

When plotted against a time scale, yields both corrosion rate and total metal loss; Can be used in any environment. Portable equipment available. On-line monitoring possible: In-plant equipment provides permanent records: Interpretation normally easy.

Disadvantages

Gives no indication of whether the corrosion rate at a particular time is high or low; portable equipment provides no permanent record.

Standards

ASTM D 1776-79

Estimated Costs

Supplier/Products

14.3.25 Hardness Test

Conditions monitored

Propriety of a material (hardness, crystallisation)

Applications

Shafts, gears, wear plates (i.e. clinker cooler), laminations, castings, welds

Technical Base

A test body is accelerated and collides with the test surface. The resistance of the material against penetration of the body into the surface is an indication of the hardness. Two types of evaluations are used depending on the method applied: A typical dimension (i.e.diameter) of the trace of the test body on the surface is measured or the energy difference of the test body is measured before or after the collision. For both methods the value is converted in hardness using tables.

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

A suitable trained operator

Advantages

Rapid and simple measurements

Disadvantages

Application in a plant limited: inaccuracy of approx. 10%, Not an on-line technique. The measurement point has to be easily accessible.

Standards

Estimated Costs

Equotip USD 4'000; Poldi USD 600

Supplier/Products

Poldy Hammer

Equotip

Shore Hardness Tester

14.3.26 Dimension Measurement

Conditions monitored

Dimensions of parts and dimension changes due to deposits or wear

Applications

For all equipment or parts such as shafts, bearings, tubes, etc.

Technical Base

There exist a wide variety of methods

A dimension is measured with a calibrator, a micrometer, etc. The results are in units of length and are compared with previous or basic values.

A dimension is compared with a calibre. The results are in a digital form , it "DOES" or "DOES NOT" have the required value including tolerances.

The contour of a part is formed with a wire and compared with the previous or basic contours.

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

No experience or special knowledge is required.

Advantages

Cheap and simple to use and evaluate

Disadvantages

Difficult to apply to big dimensions; only a decision "YES" or "NO" in the case of calibre's, not an on-line technique

Standards

ISO

Estimated Costs

Very depending on the technique selected, from USD 100 for calibrators, micrometers, etc.

Supplier/Products

14.3.27 Laser

Conditions monitored

In the majority dimensions or distances between two points are measured or it is used for alignment purposes

Applications

Kilns, transport ways, couplings, etc.

Technical Base

It is the modern form of the theodolite. A laser source is used to create an uniform and visible light of an exact wave length. This light is sent to a point on the surface. With a second instrument this point is also adjusted to this point, producing a triangulation measurements and evaluating them trigonometrically. With another Methode the beam is reflected and the difference at the source is evaluated.

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

A suitable trained technician

Advantages

Rapid, can be measured without contact, measurement possible with the equipment in service.

Disadvantages

Relatively expensive, practice is required.

Standards

Estimated Costs

Coupling alignment systems USD 10'000

Supplier/Products

Optalign FLS (kiln alignment service)

14.3.28 Theodolite

Conditions monitored

In the majority dimensions or distances between two points are measured or it is used for alignment purposes

Applications

Kilns, transport ways, coupling, etc.

Technical Base

Triangulation measurements and evaluating them trigonometrically

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

A suitable trained technician

Advantages

Rapid and relatively cheap, can be measured without contact, sometimes possible with the equipment in service

Disadvantages

Practice is required, limited use in a cement plant

Standards

Estimated Costs

Supplier/Products

14.3.29 Leak Testing

Conditions monitored

Leaks in tube systems and tanks, etc.

Applications

Distribution systems, tanks and vessel for oil, petroleum, lubricants, chemicals, liquid alternative fuels, etc.

Technical Base

The range of methods is so great that only the types are mentioned:

- by lost quantity
- by pressure differences: see also Pressure Test
- by tracing substances

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

A semi-specialized suitable trained operator. In some countries a certification is required to be allowed to perform the tests

Advantages/Disadvantages

The range of techniques is so great that the advantage of one technique is the disadvantage of the other. Some are simple to use and cheap.

Standards

BS 3636; ASTM-E 432-71

Estimated Costs

Supplier/Products

14.3.30 Voltage Generator

Conditions monitored

Resistance of electrical isolation

Applications

Electrical Circuits

Technical Base

The measurement is based on the ratiometer principle using two moving coils connected mutually at right angles (90°) within a permanent magnetic field. The reference coil is connected in series to a constant resistance, the other (deflecting coil) in series with the isolation resistance to be measured. The amount of deflection is a function of the resistance of the isolation. Test voltages of 250 to 10'000 V are used.

P-F Interval

From months to years

Experience and knowledge necessary

Operator or technician, depends on the voltage

Advantages

Simple and known technique

Disadvantages

No on-line technique

Standards

Estimated Costs

Supplier/Products

14.3.31 Magnetic Particle Test

Conditions monitored

Surface and near-surface cracks and discontinuities caused by fatigue, wear, laminations, inclusions, surface shrinkage, grinding, heat treatment, hydrogen embrittlement, laps, seams, corrosion fatigue and corrosion stress.

Applications

Ferromagnetic metals such as compressor receivers, welds, machined surfaces, shafts, steel structures, boilers, etc.

Technical Base

A test piece is magnetised and then sprayed with a solution containing very fine iron particles over the area to be inspected. If a crack exists, the iron particles will be attracted to the magnetic flux leaking from the area caused by the discontinuity and give an indication. These leakage fields act as local magnets. The indication is then interpreted and evaluated. Fluorescent magnetic particle sprays provide greater sensitivity and inspection should be carried out under ultra-violet light in a darkened room.

P-F Interval

From days to months depending on the application

Experience and knowledge necessary

Application: a suitably trained semi-specialized operator, Interpretation: an experienced technician.

Advantages

Reliable and sensitive: relatively cheap and simple; independent of temperatures

Disadvantages

Detects only surface and near surface cracks: Time consuming: Contaminates clean surfaces: Not an on-line monitoring technique; only for ferromagnetic materials.

Standards

DIN 54130 and following; BS 4397

MIL 1949; ASTM-E and ASME-SE various

Estimated Costs

USD 3'000

Supplier/Products

Tiede; Magnaflux

14.3.32 Oilproof Lacquer

Conditions monitored

Alignment, contact area

Applications Girth gear/pinion, gears

Technical Base

A coloured liquid is applied to the contact surface of one of the two parts. When the equipment is moved the coloured area comes into contact with the opposite part and leaves a "fingerprint" on it. Those are to be examined for colour distribution.

P-F Interval

Depends on the application, but usually from several weeks to months

Experience and knowledge necessary

No experience or special knowledge is required

Advantages

Cheap and simple to use

Disadvantages

There is no quantitative result; clean surfaces are required.

Standards

Estimated Costs

USD 50 per 0.2 litres

Supplier/Products

14.3.33 Electron Fractography (Replica)

Conditions monitored

The growth of fatigue cracks

Applications

Metallic components in motor vehicles, industrial equipment, etc.

Technical Base

Every fracture has its own "fingerprint", in that the history of the fracture process is imprinted on the fracture surface. By studying a replica of the actual fracture surface with an electron microscope, it is possible to establish the causes and circumstances of failures.

P-F Interval

Depending on the application

Experience and knowledge necessary

Replica of the fracture surface: suitably trained technician. Analysis and reading: experienced engineer.

Advantages

Failures can be analysed with a high degree of certainty: No damage caused the actual to fracture surface when replica is made.

Disadvantages

Electron microscope is expensive: High degree of specialisation required to read the results: Not an on-line monitoring technique: Inaccessible components must be dismantled.

Standards

DIN 54150

ISO 3057

Estimated Costs

Supplier/Products

14.3.34 Pressure Test

Conditions monitored

Leaks, fissures, fractures and deformations in tanks, pressure vessels, etc.

Applications

Tanks for, gas, pressured air, etc.

Technical Base

For security reasons the tests should be carried out using water or oil if possible. The systems have to be adequately ventilated. Higher pressures than required during operation are introduced to the system to see if it can withstand them. The percentage of overpressure required before rupture, depends on the safety regulations applicable.

P-F Interval

"YES" or "NO" decision

Experience and knowledge necessary

A semi-specialized suitably trained operator. In some countries certification is required before testing can be carried out.

Advantages

This test can be combined with a leak test, cheap and simple to do.

Disadvantages

Not an on-line technique, The components have to be emptied and cleaned before and after the test.

Standards

BS 5430

Estimated Costs

Supplier/Products

14.3.35 Radiography (X-Ray)

Conditions monitored

Surface and sub-surface discontinuities caused by fatigue, stress, inclusions, lack of penetration in welds, gas porosity, intergranular corrosion and stress corrosion.

Applications

Ferrous and non-ferrous materials, welds, steel structures, plastic-structures, metallic wear components of engines, compressors, gearboxes, pumps shaft, etc.

Technical Base

A radiograph is produced by passing x-rays or gamma rays through materials which are optically opaque. The absorption of the initial x-ray depends on thickness, nature of the material and intensity of the initial radiation. The areas exposed become dark when the film is developed. The degree of darkening depends on the amount of radiation reaching the film. It will be darkest where the object is thinnest. A crack, inclusion or a void is observed as a dark patch.

P-F Interval

Several months

Experience and knowledge necessary

Use of equipment: a suitably trained and skilled technician. To interpret the results: a highly skilled technician or engineer.

Advantages

Provides a permanent record, detects defects in parts or structures not visually accessible

Disadvantages

Sensitivity often low on crack-line defects: Two-sided access sometimes needed; external expert required; security precautions elevated; costly

Standards

Estimated Costs

USD 6'000 - 300'000

Supplier/Products

Specialised companies

14.3.36 Linear Polarisation Resistance (Corrator)

Conditions monitored

The rate of corrosion in electrically conductive corrosive fluids

Applications

Cooling water systems, municipal water systems, heat exchanger, desalination plants and pulp and paper mills and in the plants where the measurement and/or the corrosion control is required in acid water systems

Technical Base

Corrosion rate is measured by the electro-chemical polarisation method with two or three probes and a measuring instrument. The principle is based on the fact that a small voltage applied between a metal specimen and a corrosive solution will produce a current. The ratio of voltage to current is inversely proportional to the corrosion rate so it provides a measure of the corrosion rate increase.

P-F Interval

Depends on the application and the corrosion rate. Usually several months

Experience and knowledge necessary

A suitably trained operator

Advantages

Provides a direct indication of the corrosion rate and pitting tendency: Measures corrosion as it occurs: Some instruments provide a record of the corrosion condition: Automatic detection and control available: Sensitive to very low corrosion rates: Portable equipment available: Rapid measurement: Interpretation normally easy

Disadvantages

Portable equipment does not provide a permanent record: Readings must be adjusted when taken in high sensitivity corrosive media: Gives no information on total corrosion.

Standards

ASTM D 2776

Estimated Costs

Supplier/Products

14.3.37 Liquid Chromatography

Conditions monitored

Changes in lubricant properties such as alkalinity, acidity, ash, flash point, insoluble, viscosity, etc.

Applications

Enclosed oil systems such as transformers, engine sumps, compressor sumps, hydraulic systems, etc.

Technical Base

Liquids are selectively absorbed by passing through a column of finely divided absorbent material. The separate liquids are then set free by passing a mixture of two solvent liquids, with different polarities, through the column. Light liquids appear first from the column and complex liquids last. The analysis appears on a strip chart recorder, or a screen, and the area under each peak is measured to determine the respective liquid concentrations

P-F Interval

Depending on the degradation rate of the lubricant and the application, but usually several weeks.

Experience and knowledge necessary

Operating the equipment and interpretation of results: a laboratory technician who has passed a course of chromatography.

Advantages

High sensitivity: Quick sampling and analysis: Strip chart provides a permanent record

Disadvantages

Considerable skill is needed to interpret results: Equipment not portable: Wide range of applications required to justify purchase: Not an on-line monitoring technique: not widely used in maintenance

Standards

Estimated Costs

Supplier/Products

14.3.38 Ultrasonic

Conditions monitored

Surface and below surface discontinuities caused by fatigue, heat treatment, inclusions, lack of penetration and gas porosity in weld, laminations, etc. as well as material thickness.

Applications

Ferrous and non-ferrous materials related to welds, steel structures, boilers, boiler tubes, plastic structures, shafts, compressor receivers, etc.

Technical Base

A transmitter sends an ultrasonic pulse into the test surface and a receiver amplifies the return pulse to an oscilloscope. The echo is a combination of return pulses from the opposite side of the test piece and from any intervening discontinuity. The time elapsed between the initial and return signals and the relative height indicate the location and severity of the discontinuity. A rough idea of the size and shape of the defect can be gained by checking the test piece from another location.

P-F Interval

From several weeks to several months

Experience and knowledge necessary

An experienced and suitably trained technician

Advantages

Applicable to the majority of materials, relatively low costs, no expensive preparations needed

Disadvantages

Difficult to differentiate types of defects, evaluation relatively difficult; Problems with complex geometrical pieces, superficie has to be machined.

Standards

Estimated Costs

USD 8'000

Supplier/Products

Krauträmer; Karl Deutsch

14.3.39 Potential Monitoring

Conditions monitored

Corrosive states of plant (active or passive) such as stress-corrosion cracking, pitting corrosion, selective phase corrosion, impingement attack, etc.

Applications

Electrolyte environments such as chemical process plants, paper mills, electrical generating plant, pollution control plants, desalination plants, etc. best suited to materials of stainless steel, nickel-based alloys and titanium

Technical Base

This technique takes advantage of the fact that, from the point of view of corrosion, a metal which is in a passive state (low corrosion rate) has a noble corrosion potential, while the same metal in an active state (higher corrosion rate) has a much less noble potential. The potential changes when passivity breaks down, and measurements can be made using a voltmeter of about 10 megohm input impedance and full-scale deflection of 0.5 to 2 volts

P-F Interval

Depends on the material and the corrosion rate

Experience and knowledge necessary

Signal detection is normally easy, but sometimes an experienced engineer is needed to interpretate de results further

Advantages

Monitors localised attack: Fast response to change

Disadvantages

Small potential changes can be influenced by changes in temperature or acidity: Does not give a direct measure of corrosion rate or total corrosion: Not widely used: Expert assistance may be required for interpretation

Standards

Estimated Costs

Supplier/Products

Rohrback Instruments